BNL-93892-2010-CP

Energy-Water Nexus

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BROOKHAVEN NATIONAL LABORATORY

a passion for discovery

Office of Science U.S. DEPARTMENT OF ENERGY

Presentation Outline

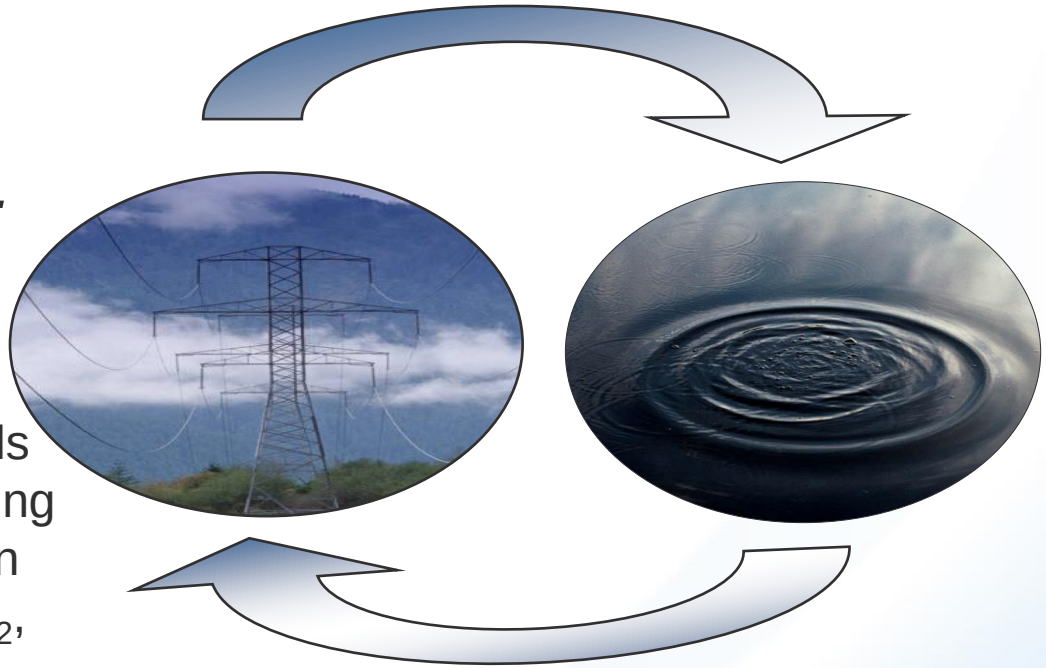
- Energy Water Nexus
- National Laboratory Team
  - Report to Congress
  - Technical Workshops
  - Roadmap
- Energy-Water Issues in New York State
  - BNL-EPRI-Columbia 2004 Workshop
  - New York City Pilot Study
  - NYDEC Indirect Cooling Order and Potential Responses
- Lessons Learned

Energy and Water are … Interdependent

Water for Energy **and** ***Energy for Water***

Energy and power production require water:

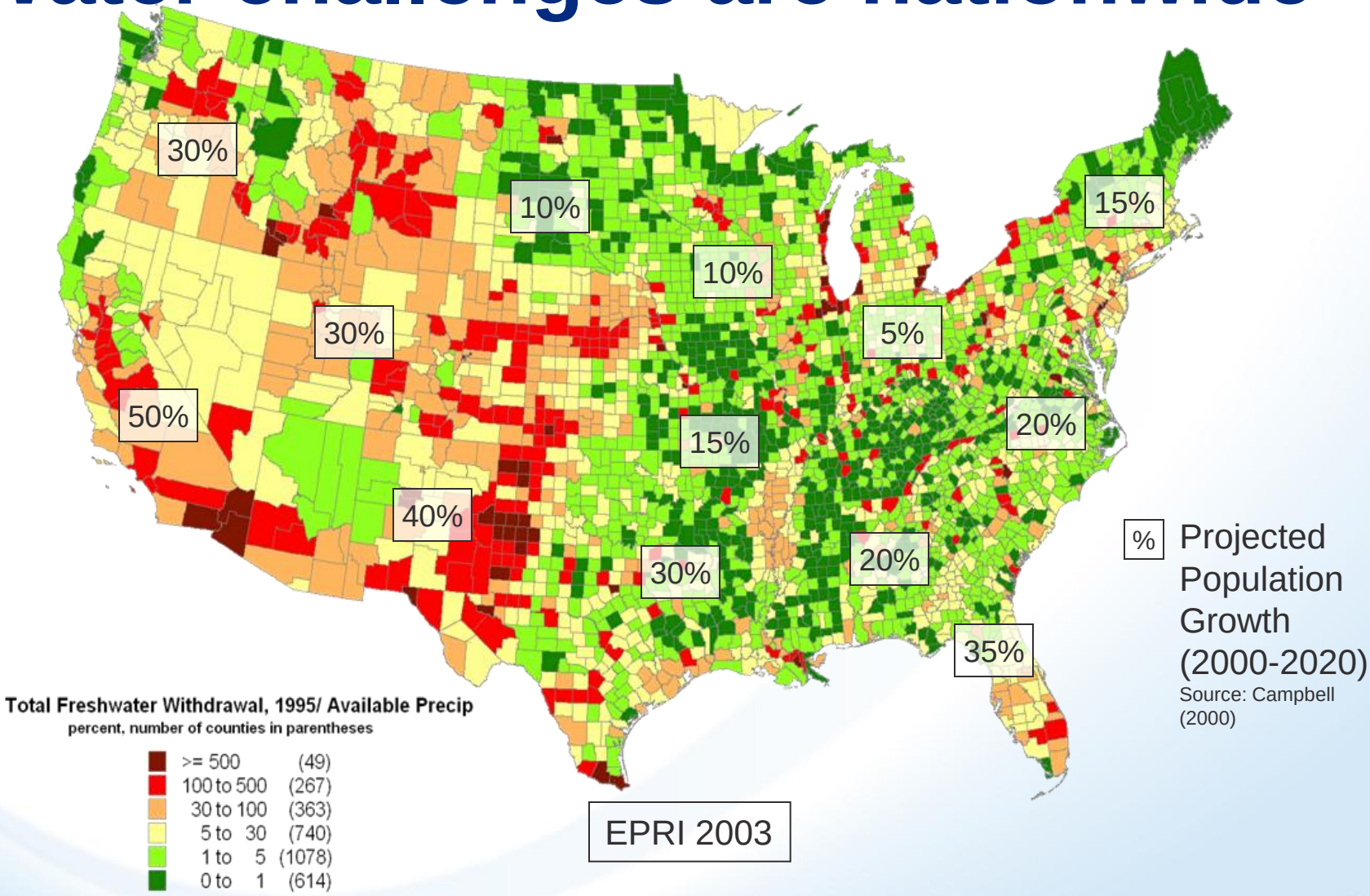
- Thermoelectric cooling
- Hydropower
- Energy minerals extraction/mining
- Fuel Production (fossil fuels, H_2, biofuels)
- Emission control



Water production, processing, distribution, and end-use require energy:

- Pumping
- Conveyance and Transport
- Treatment
- Use conditioning
- Surface and Ground water

Water challenges are nationwide



2003 Heat Wave Impact on French Electric Power Generation

- Loss of 7 to 15% of nuclear generation capacity for 5 weeks
- Loss of 20% of hydro generation capacity
- Large-scale load sheddir and shut off transmissior Italy
- Sharp increase of spot-market prices: 1000 to 1500 $ / MWh for most critical days

Normal conditions in August

Bort-les-Orgues Réservoir

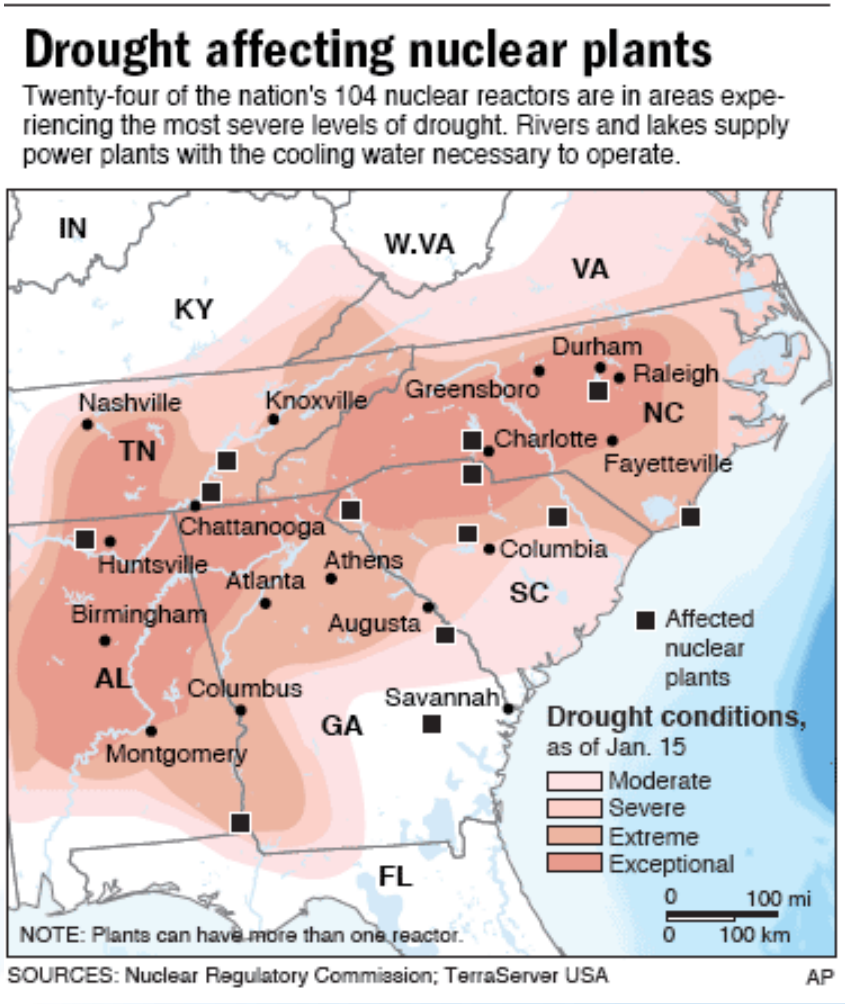
August 27, 2003

Contemporary Example: Southeast U.S. Drought Impact on Nuclear Power Production

Associated Press

Jan. 23, 2008

"LAKE NORMAN, N.C. - Nuclear reactors across the Southeast could be forced to throttle back or temporarily shut down later this year because drought is drying up the rivers and lakes that supply power plants with the awesome amounts of cooling water they need to operate."



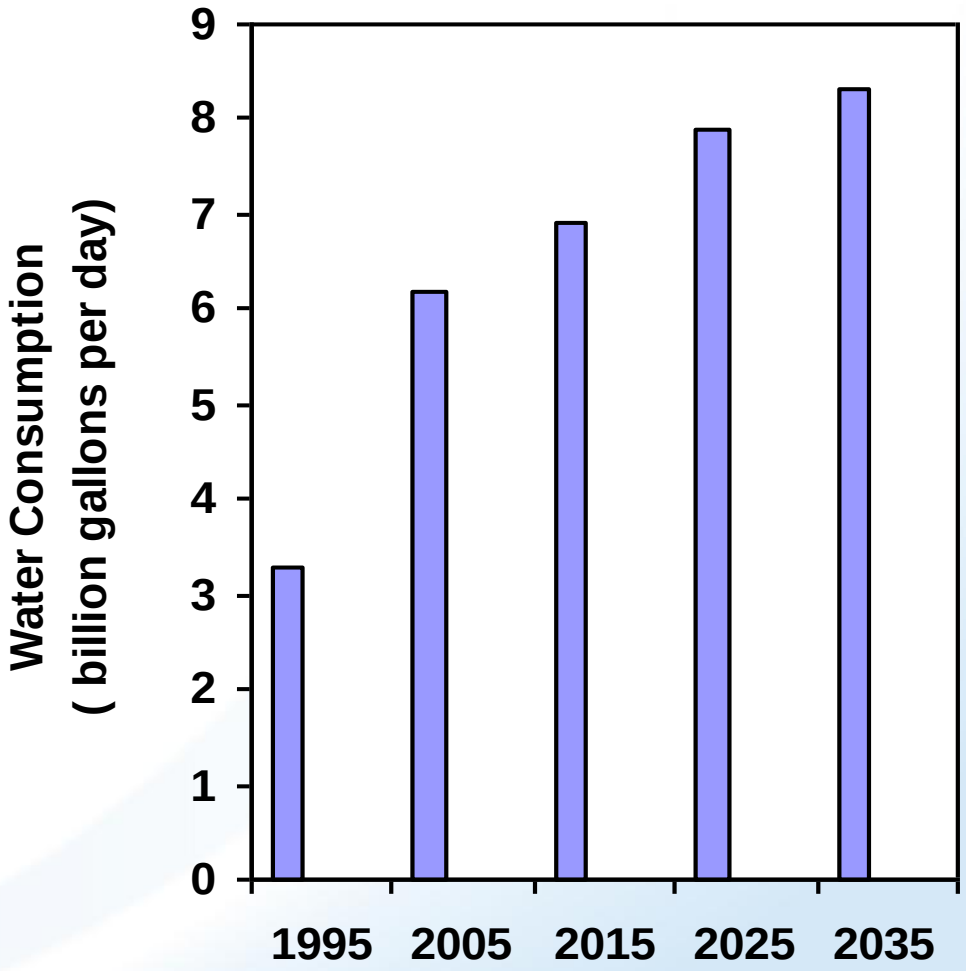
Water Use and Consumption for Electric Power Generation

Plant-type	Cooling Process	Water Use Intensity (gal/MWh$_e$)		
		Steam Condensing		Other Uses
		Withdrawal	Consumption	Consumption
Fossil/ biomass steam turbine	**Open-loop**	**20,000–50,000**	**~200-300**	**~30**
	Closed-loop	**300–600**	**300–480**	
Nuclear steam turbine	**Open-loop**	**25,000–60,000**	**~400**	**~30**
	Closed-loop	**500–1,100**	**400–720**	
Natural Gas Combined-Cycle	**Open-loop**	**7,500–20,000**	**100**	**7–10**
	Closed-loop	**230**	**180**	
Integrated Gasification Combined-Cycle	**Closed-loop**	**200**	**180**	**150**
Carbon sequestration for fossil energy generation	**~25% increase in water withdrawal and consumption**			
Geothermal Steam	**Closed-loop**	**2000**	**1350**	**50**
Concentrating Solar	**Closed-loop**	**750**	**740**	**10**
Wind and Solar Photovoltaic	**N/A**	**0**	**0**	**1-2**

Water Demands for Future Electric Power Development

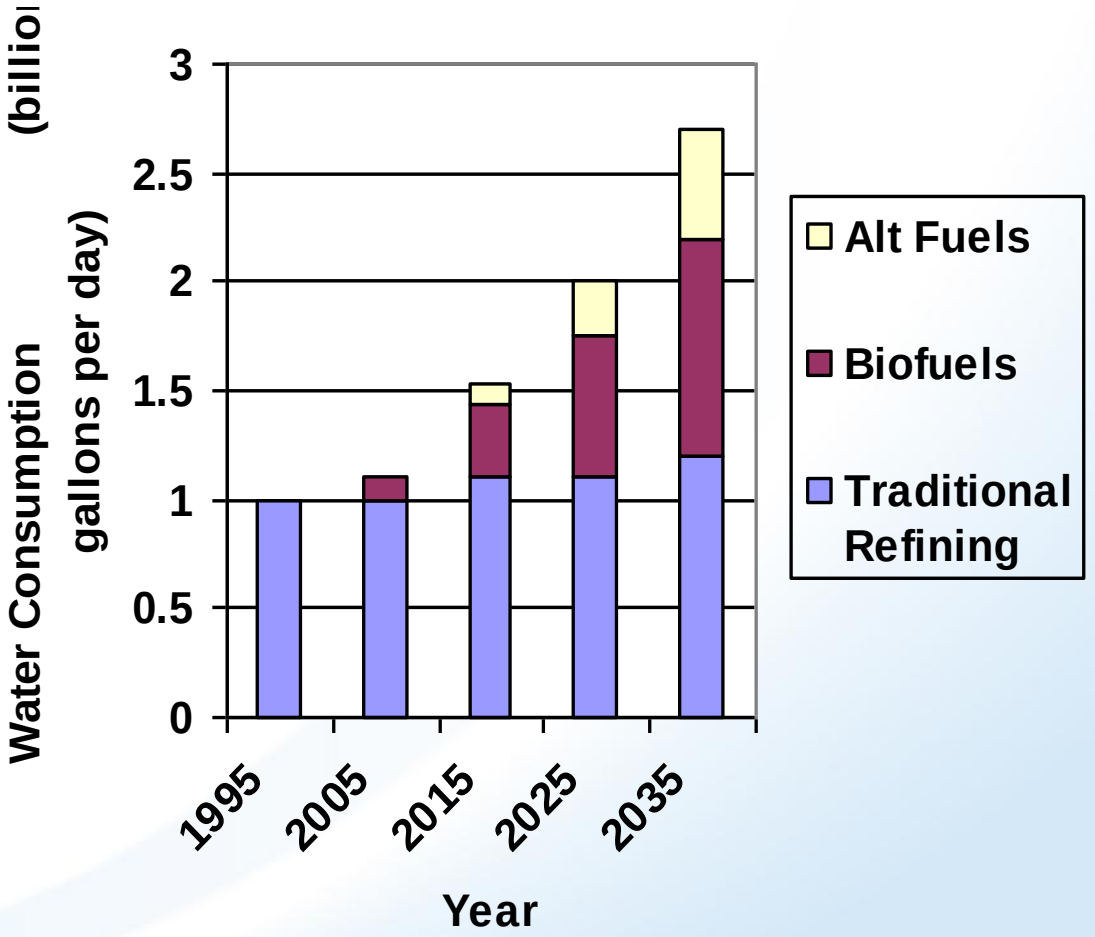
- Water demands could almost triple from 1995 consumption for projected mix of plants and cooling
- Carbon emission requirements will increase water consumption by an additional 1-2 Bgal/day

Source: NETL 2006



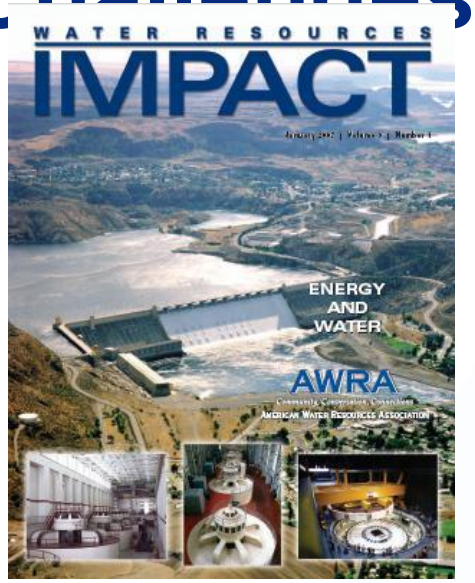
Emerging Water Demands for Alternative Fuels Development

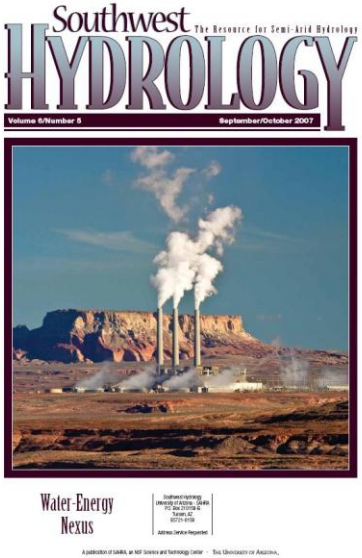
- Irrigation of even small percentage of biofuel acreage will increase water consumption by an additional 3-5 Bgal/day

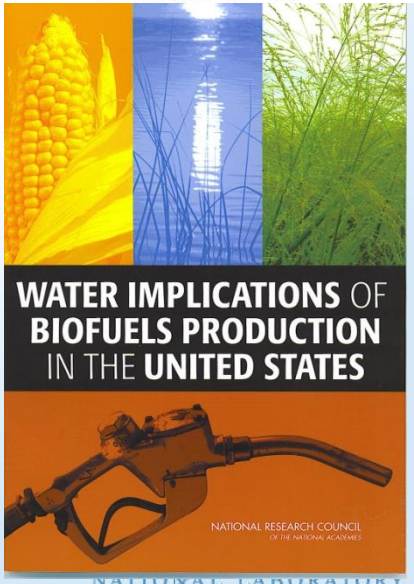


Emerging Interest in Energy and Water Issues and Challenges

- State and national water and energy groups
  - 24 invited presentations in FY07 and 08 on energy and water challenges
  - Research and regulatory groups considering future energy and water needs
- Increased media interest
  - NATURE, ECONOMIST
  - Technical magazines
- NSF/NRC interest in energy debate and interdependencies research
- Growing international concerns and challenges
  - Europe, Australia, Asia, Canada







Energy Water Nexus National Laboratory Team

- Initiated in 2004 (Erik Webb, SNL)
- Involved all11 DOE Multi-program Laboratories
- Goals
  - Define the problem
  - Report to the Congress
  - Regional Technical Workshops
  - Pilot Studies
  - Roadmap

Energy Water Roadmap Overview

- Three regional needs assessment workshops: Nov 2005 through mid-January 2006
  - Kansas City, Baltimore, Salt Lake City
  - Almost 350 participants from 40 states involved
  - Focus on emerging user and stakeholder problems and challenges and science and technology role in effective solutions – captured high-level issues, needs, and directions
- Broad spectrum of regional, state, and local participation and input
  - Representatives from energy companies, electric utilities, water utilities, water managers, economic development groups, energy regulators, environmental groups, tribal nations, other water-use sectors
- Gaps and Technical Innovations Workshops to capture science and technology research and development priorities
  - Almost 150 researchers and technology developers involved

Energy-Water Regional Needs Workshops

- Congressionally funded and coordinated with DOE
- Coordinated by Sandia with support from all the national laboratories
- Needs driven research directions and solutions focus

Roadmap Regional Needs Workshops

Summary of Major National Needs and Issues Identified in Regional Workshops

Better resources planning and management

- Integrated regional energy and water resource planning and decision support tools
- Infrastructure and regulatory and policy changes for improved energy/water efficiency
- Improved water supply and demand characterization, monitoring, and modeling

Improved water and energy use efficiency

- Improved water efficiency in thermoelectric power generation
- Improved biofuels/biomass water use efficiency
- Reduced water intensity for emerging energy resources

Development of alternative water resources and supplies

- Oil and gas produced water treatment for use
- Energy efficiency and assessment of impaired water treatment and use

www.sandia.gov/energy-water

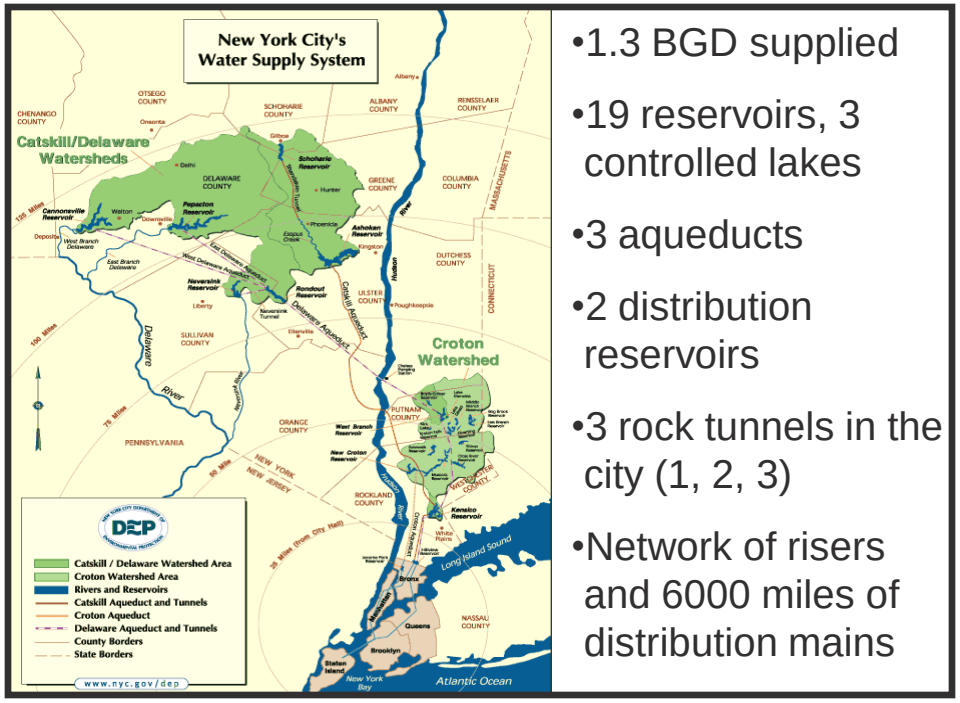
New York Energy Water Activities

- ***2004 Workshop with EPRI and Columbia on NY State Energy Water Issues—316(b) issues***

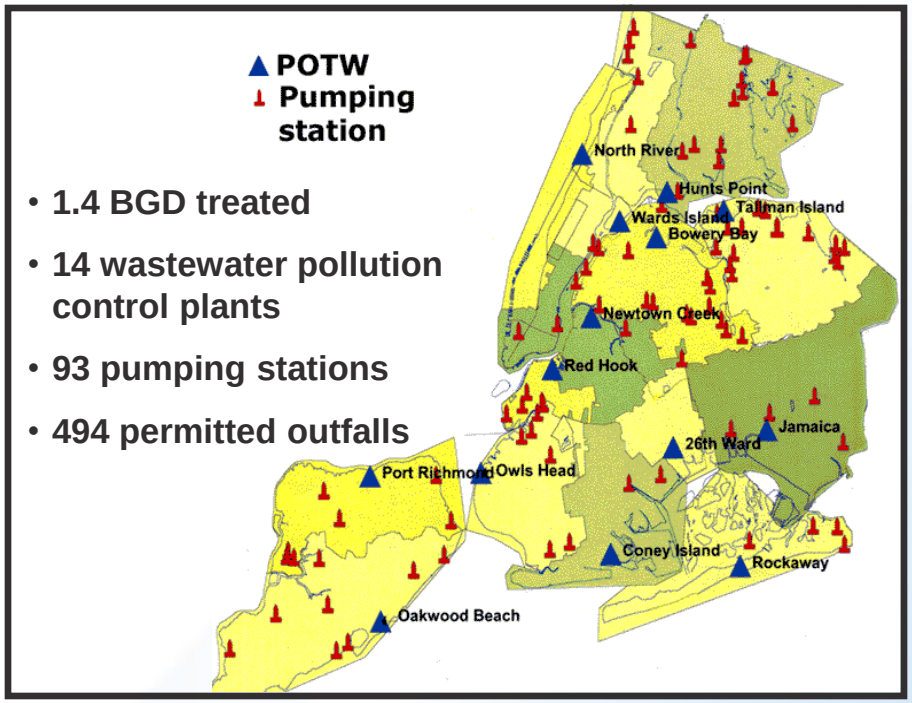
- ***New York City Pilot Study (2006-2008)Goals:***

- Determine the key energy-water planning issues for an urban area - New York City
- Develop and apply an integrated energy-water decision-support tool to facilitate urban energy-water planning
- Identify the activities and framework needed to achieve successful integrated energy-water planning
  - Challenges (regulatory/policy issues, data, necessary tools, programmatic issues, etc.)
  - Suggestions for steering committee establishment and the interactions and activities of the steering committee
  - Development and application of tools and methods

New York City Study Area



- 1.3 BGD supplied
- 19 reservoirs, 3 controlled lakes
- 3 aqueducts
- 2 distribution reservoirs
- 3 rock tunnels in the city (1, 2, 3)
- Network of risers and 6000 miles of distribution mains



- **1.4 BGD treated**
- **14 wastewater pollution control plants**
- **93 pumping stations**
- **494 permitted outfalls**

Area: 321 mi^2 (~ 830 km^2); Population: 8,213,839

Energy Supply: Keyspan, Reliant Resources, NRG Energy, and NYPA

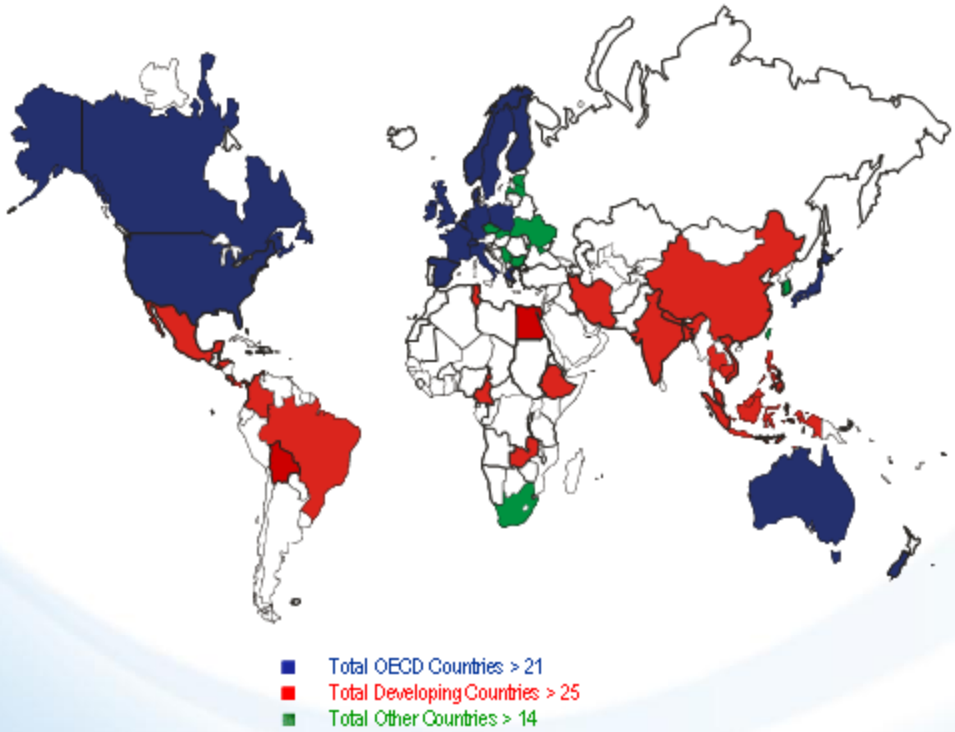
Distribution: Consolidated-Edison

Forecasted peak electricity demand 11,020 MW (80% in-City generation) 2003

By *2008*, *3,780 MW of new electricity resources needed*

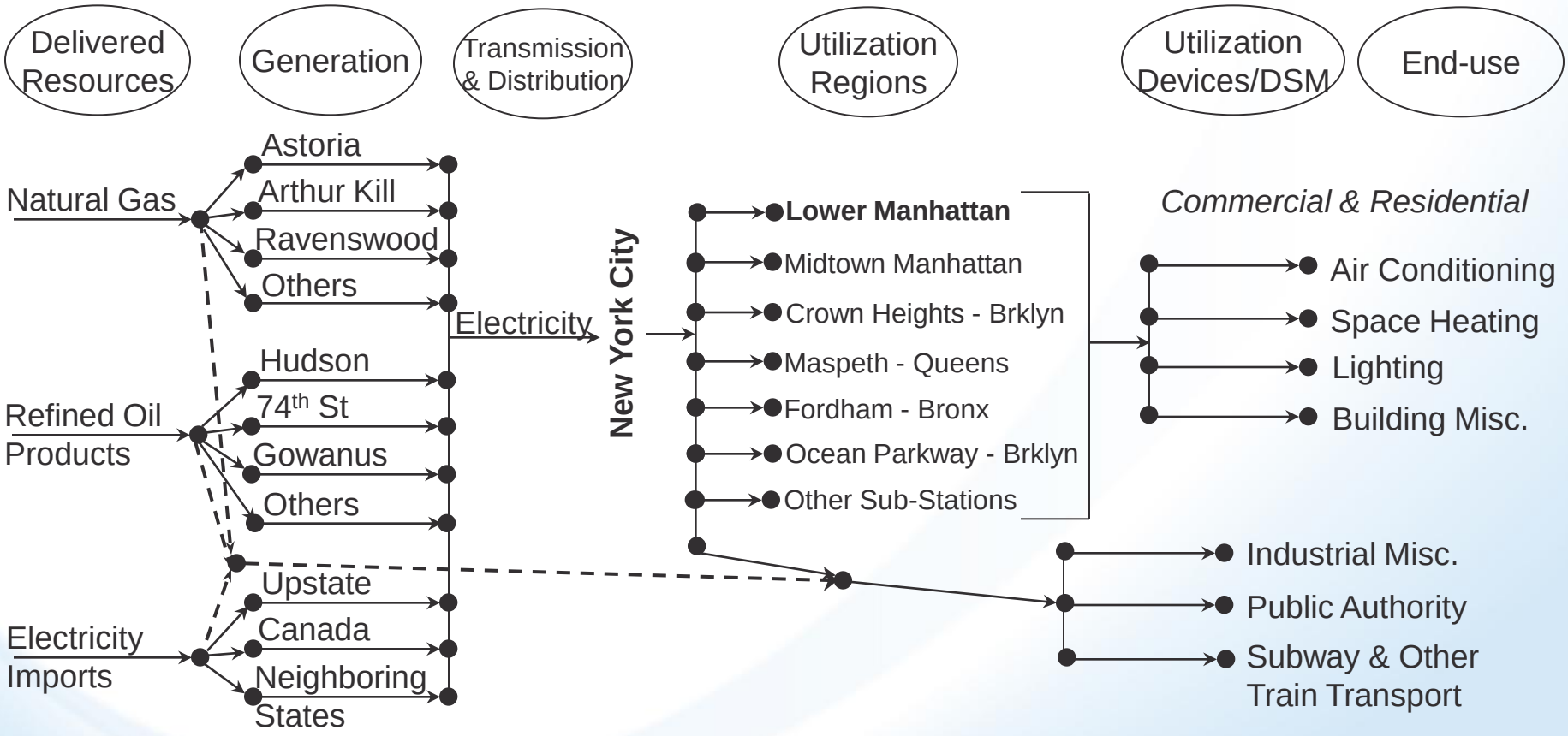
Decision Support Tool: MARKAL

- ***Developed at BNL*** in 1970s in collaboration with IEA (International Energy Agency) – continuously updated/validated
- ***Flexible*** and ***transparent*** framework with a ***well documented*** methodology



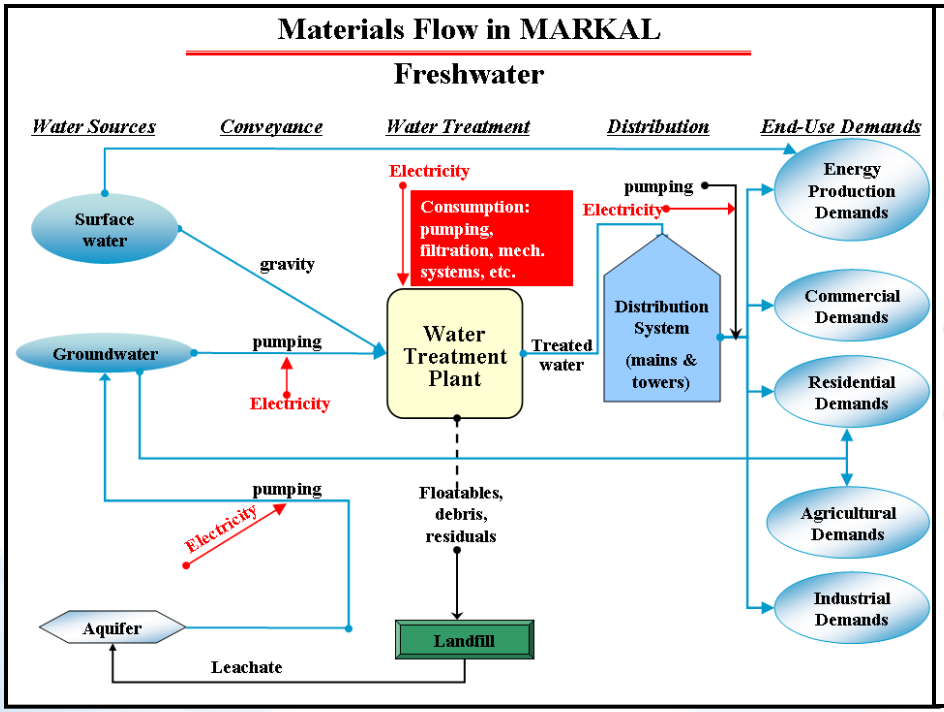
- ***Over 100 institutions*** in ***55 countries*** currently use it for energy systems analysis
- Use of MARKAL at ***U.S. DOE R&D policy decisions***
  - Applied R&D Programs (NE, EERE, FE & OE) – GPRA 1993
  - Office of Nuclear Energy – GNEP
  - Office of Policy and International Affairs
  - Hydrogen Economy
  - Energy-Water Nexus

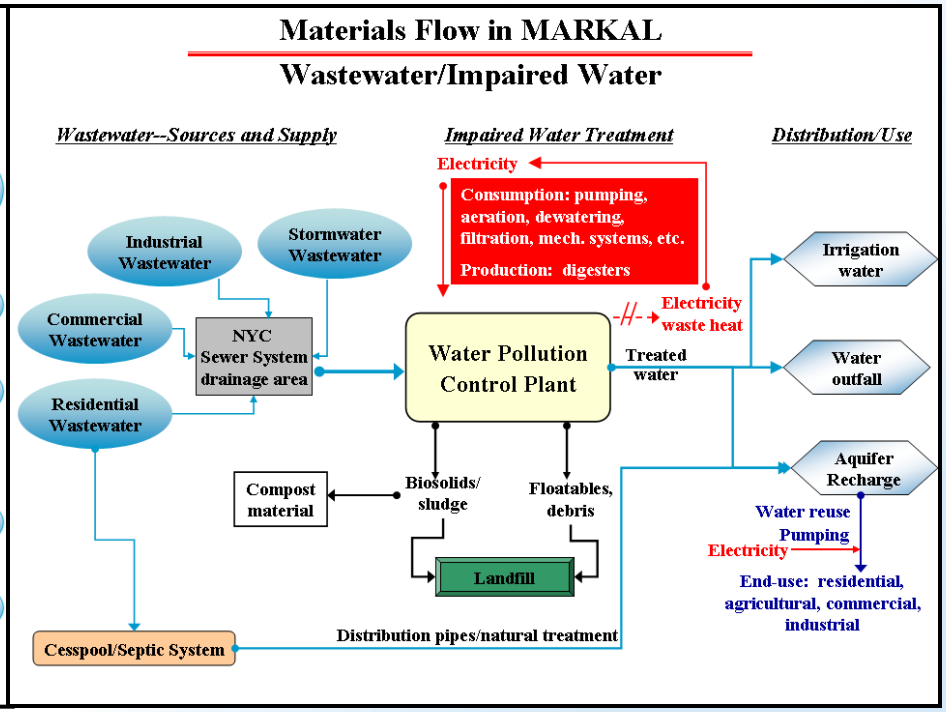
Reference Energy System



Modeling Water Systems

- Detailed fresh and wastewater flows and technologies



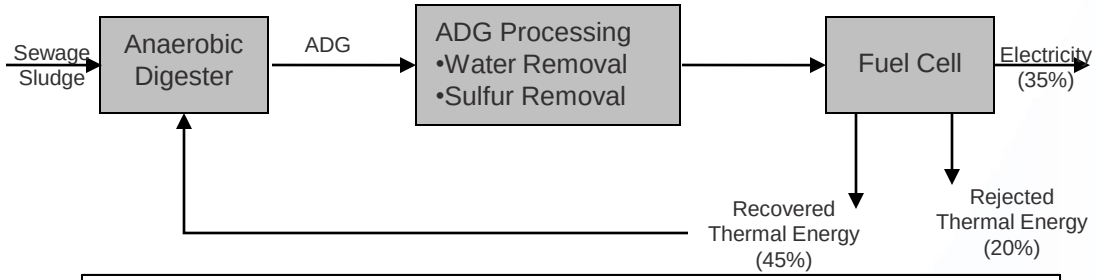


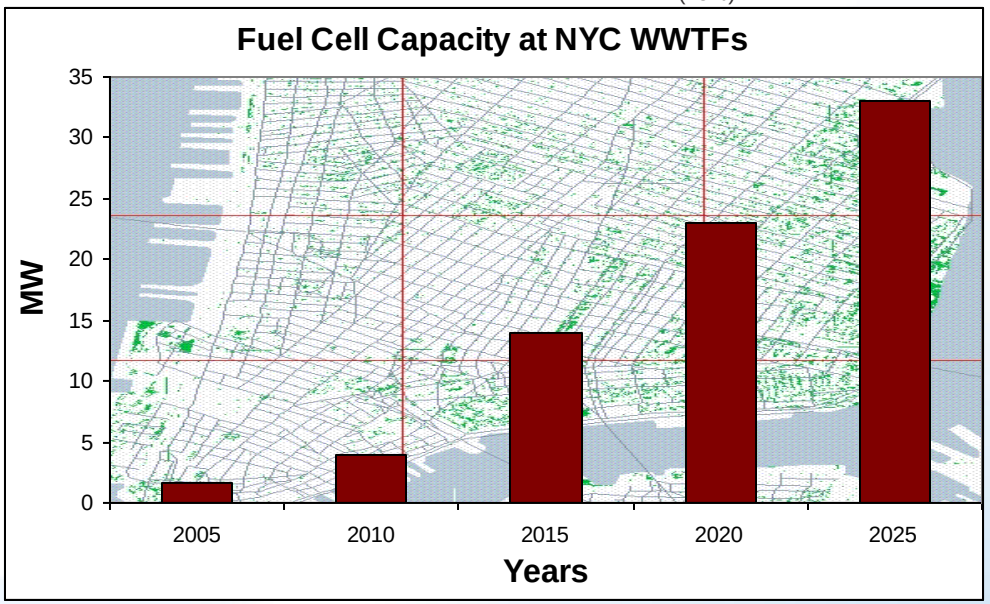
Policy Options Analysis

Several **energy-water integrated planning scenarios** were developed, based on issues identified by the steering committee.

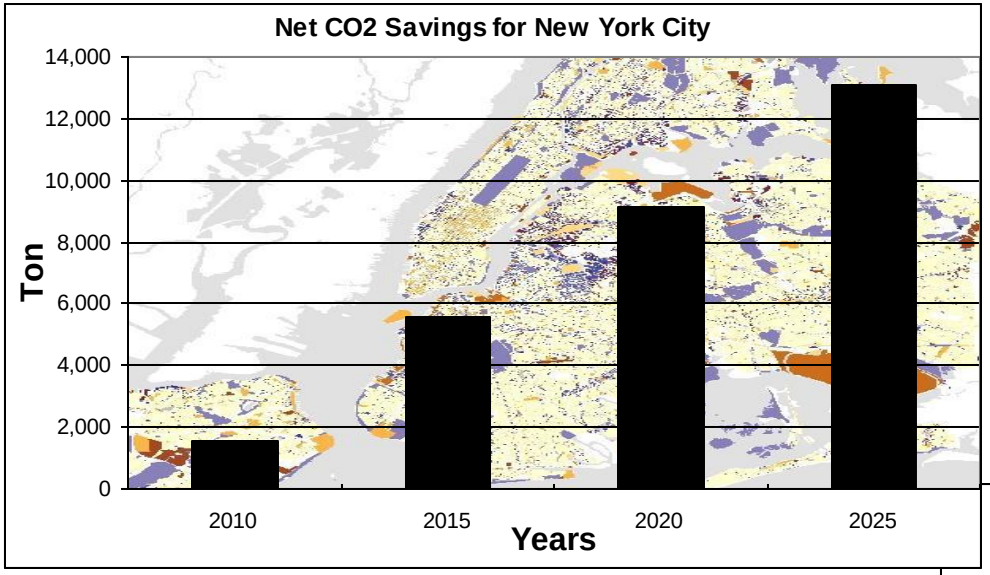
- *Scenario 1:* Water-Efficient Appliances: Energy and Water Use Impacts
- *Scenario 2:* WasteWater Treatment: Deploying More Fuel Cells
- *Scenario 3:* New York City Water Supply: Impacts of Increased Energy Demands for New Treatment
- *Scenario 4:* New York City Steam Generation: Water Supply and Energy Impacts
- *Scenario 5:* Climate Change Models and Research: A Link with Energy and Water

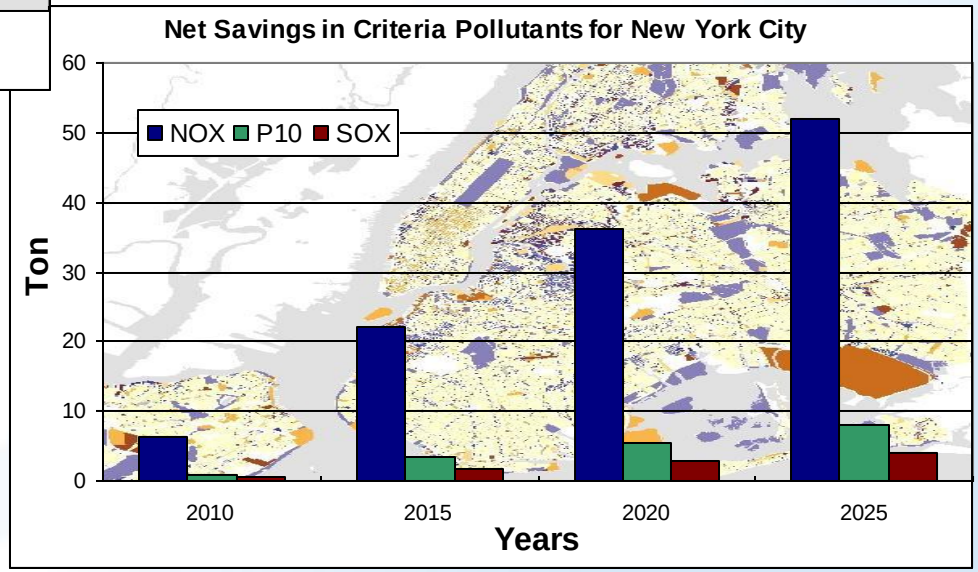
Scenario 2
Wastewater Treatment: Deploying More Fuel Cells





Scenario 2
Fuel Cells





NY DEC Closed Loop Cooling

NY water plan could cost power generators billions

Fri, Mar 12 2010

By Scott DiSavino

NEW YORK (Reuters) - New York environmental regulators this week released a plan to protect aquatic life in the state's rivers that could cost power generators billions to upgrade their facilities.

The plan, which still needs final approval, would affect most of the state's six nuclear power plants and several facilities powered by fossil fuels that use water for cooling. The state Department of Environmental Conservation (DEC) wants the facilities to recycle and reuse the water in a closed-cycle cooling system rather than discharging the heated water into rivers.

One of the first plants to face the proposed regulations would be Entergy Corp's 1,910-MW Indian Point located about 45 miles north of New York City where it draws water from the Hudson River. Entergy has already asked the DEC for a new water permit and requested that the federal government renew the license for both of its reactors.

The DEC, which is accepting comment on its proposal through May 9, said it would require closed-cycle systems -- like cooling towers -- unless "an operator can demonstrate that closed-cycle cooling technology cannot physically be implemented at a particular location."

In February, Entergy filed a report with the DEC that found it would be better to add new underwater screens to the plant's existing cooling water intake system rather than install expensive cooling towers.

The state however wants plants to use closed-cycle systems, which recirculate the water instead of discharging it after one use. The DEC said closed-cycle systems reduce the impact on aquatic life by more than 90 percent.

Like the other plants, Indian Point uses river water to condense the steam used to turn the turbines and generate electricity before returning the slightly heated water back to the river. The water used to make the steam remains in the plant.

Entergy said cooling towers, which can stand more than 600 feet tall and measure 300 feet in diameter, could not enter service before 2029 at an estimated cost of $1.5 billion to $2 billion.

The underwater screen meanwhile would take just three years to install and cost about $100 million.

Hence Entergy said the screens would better protect fish eggs and larvae over the 20-year period of a renewed Indian Point license in large part, because they can be installed 12 to 15 years sooner than cooling towers. Entergy has said it hopes to get a draft water permit from the DEC in April that included approval for the screens.

Entergy is also waiting for the U.S. Nuclear Regulatory Commission to decide on 20-year extensions of the reactors' original 40-year operating licenses, which expire in 2013 and 2015.

Entergy filed to renew both reactors' licenses in 2007. The NRC, which has made decisions on other renewals in 22 months without a hearing, has not said when it will decide on Indian Point.

Electricity traders noted contentious applications with hearings, such as Indian Point, can drag on for years.

The DEC plan would also affect other power plants in the state, including U.S. Power Generating's 1,290-megawatt Astoria, Mirant Corp's 1,139-MW Bowline, National Grid's 1,522-MW Northport, Oswego Harbor's 1,700 MW Oswego, TransCanada's 2,410-MW Ravenswood and Dynegy Inc's 1,200-MW Roseton.

(Reporting by Scott DiSavino; Editing by Lisa Shumaker)

Indian Point License Extension

DEC rejects permit for Indian Point Action against nuclear power facility hailed as victory for Hudson River By **MICHAEL GORMLEY**, Associated Press First published: Sunday, April 4, 2010ALBANY -- New York state has denied a water quality permit the Indian Point nuclear facility near Manhattan needs for federal re-licensing in what environmental advocates call a historic victory in protecting the Hudson River.The Department of Environmental Conservation says that data from the past 35 years show that the Entergy Corp. facility has been harming aquatic organisms as it draws up to 2.5 billion gallons of water a day from the Hudson River to cool its two nuclear units, then returns the warm flow to the river.The DEC says Entergy's proposed 20-year continued operation "would continue to exacerbate" the harm done to fish including sturgeon, fish eggs and larvae, and the company has acknowledged radioactive material from the site continues to get into the groundwater.Entergy could request a hearing, challenge the decision or seek an extension from the Nuclear Regulatory Commission. The power plants are about 35 miles north of Manhattan in the Westchester County town of Buchanan.Assemblyman Richard Brodsky of Westchester said diverting the water then returning it untreated is the "most destructive force on the Hudson River it in its history." As an attorney, Brodsky has brought lawsuits against the state and federal government in the issue to force a decision on the water permit."This is finally the definitive ruling about the massive destruction Indian Point has caused for the river," he said Saturday. "This is the beginning of the end of this massive destruction of the river."Entergy countered in a statement Saturday saying the action by the Department of Environmental Conservation isn't final."It is a draft departmental proposal, and an interim step in further proceedings which may include a hearing before a DEC administrative law judge. This action does not stay the NRC's ongoing proceedings regarding license renewal for Indian Point," the statement says.Alex Matthiessen, president of the environmental watchdog Riverkeeper, said the state made a clear denial that says the plant can't -- as required for its federal license -- operate without damaging the waterway.

Options

- Better Screens
  - Probabilistic Analysis
  - Ecological Studies
- Closed Loop Cooling
  - Costly
  - Land Area Issues
  - Time Scale
- Dry Cooling
  - Big Footprint
  - Bilibino Power Plant
- Hybrid Cooling

- Alternate Water Sources
  - Palo Verde Solution
  - Competition
- All options have an energy penalty (and a possible RGGI impact)
  - 1-3% energy loss
  - 2-8% loss in capacity

Summary

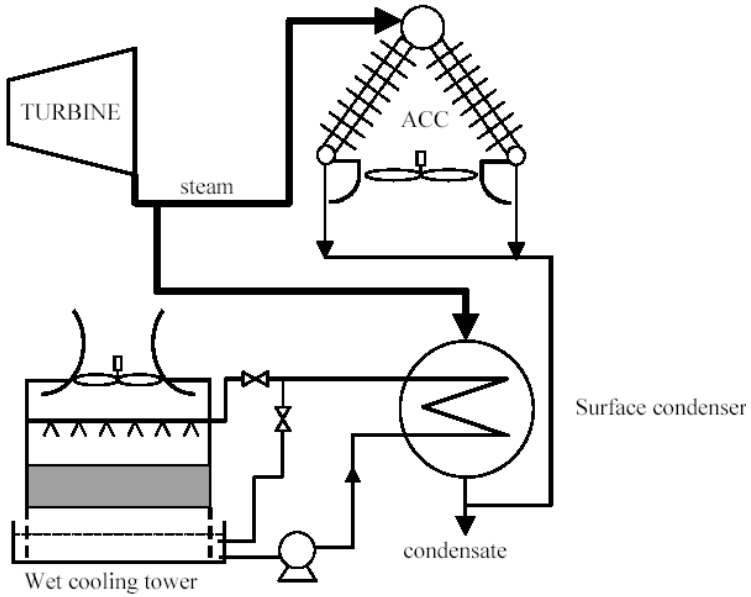
- Energy and Water are interconnected
- New energy sources will place increased demands on water supplies
- Existing energy sources will be subjected to increasing restrictions on their water use
- Integrated Decision support tools will need to be developed to help policy makers decide which policies and advanced technologies can address these issues

Special Thanks

- Mike Hightower, Sandia National Laboratory
- The Energy~Water Nexus National Laboratory Team
- Vatsal Bhatt, Brookhaven National Laboratory
- Ann Reisman, Brookhave National Laboratory
- Kenya Crosson, University of Dayton

Backup Slides

Research Program for Electric Power Sector



Hybrid Wet-Dry Cooling System

- Improve dry and hybrid cooling system performance
- Improve ecological performance of intake structures for hydro and once-through cooling
- Improve materials and cooling approaches compatible with use of degraded water
- Electric grid infrastructure upgrades to improve low water use renewable technology integration